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HAROLD L. ICKES, SECRETARY

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INFORMATION CIRCULAR

MINE VENTILATION

BY

D. HARRINGTON

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

MINE VENTILATION[1]

By D. Harrington[2]

Mine ventilation was discussed much more 15 to 20 years ago than it is now, yet today there are tendencies in connection with mine ventilation (in fact, numerous ventilation systems have been installed in recent years) indicating that the lessons learned by bitter experience in the past either have been forgotten or have not been brought to the attention of the present generation. Possibly, the mining man of today considers that conditions have changed so much that experiences of the past cannot be repeated today. At any rate, it seems desirable to restate some of the principles of mine ventilation that were understood more or less in the past and to call attention to some dangers in connection with present-day trends or practices.

Some of the more seriously dangerous trends in mine ventilation are the placing of the main fan underground in coal mines, a very dangerous practice and one very likely to cause disaster if it becomes widespread; the placing of the main fan underground in metal mines is somewhat hazardous but is by no means as dangerous as in coal mines. In many recent main-fan installations on the surface of coal mines the fan has been placed in a direct line with the mine opening - a hazard, since the fan is likely to be destroyed or be damaged seriously in case of an explosion. The main fan for a coal mine should certainly be placed on the surface in fireproof housing and should be offset at least 25 feet from the line of the mine opening, while explosion doors that can be opened easily should be provided to relieve pressure in case of an explosion. Many metal mines, partly to reduce air dustiness and partly to prevent formation of ice in working shafts, are installing ventilation systems with the working shaft on return air. This is extremely hazardous where the workers must be transported through the shaft, because in case of fire the shaft is very likely to be filled with poisonous gases and the men in the mine trapped or killed. Safety demands that the man-hoisting shaft be safeguarded by being built in either intake or downcast air with provision for pre-heating it in winter, or, preferably, the man-hoisting shaft should be essentially neutral as to air flow, with only enough fresh air to keep it free of gases or undue cold or humidity, other shafts or openings to provide ingress for fresh air and egress for vitiated air.

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Most mine-ventilation installations are intended to achieve only some of these objectives and consequently fail to protect the mine worker or the mine to anything like the extent they should; and in many cases the slipshod or poorly planned and operated ventilating system is a menace to either safety or health, or both. In fact, many of the worst disasters in both coal and metal mines have been due to glaring defects in elaborate and relatively costly mine ventilation systems and installations.

Effective ventilation of underground workings requires the establishment and maintenance of such control of air currents that the underground workers may work in safety with maximum comfort and efficiency and without impairment of health; and that the mine openings may be made subject to such flow of air as to remove from the workings at ordinary times harmful gases and dusts; and that at times of emergency, such as fire or explosion, there may be circulated as much or as little air as may be desired, covering portions of the mine or the mine in its entirety.

Control of air flow is absolutely necessary in any ventilating system, and this very essential feature is obtainable only by the installation of mechanically operated fans and other ventilating devices, such as doors, overcasts, regulators, etc. Every mine, large or small, coal or metal, should be equipped with a fan from the outset. While much has been written about natural ventilation and many claims have been made that in specific mines there is sufficient natural air flow, there are few, if any, mines, coal or metal, where natural ventilation supplies anything like adequately safe or healthful conditions for underground workers even at ordinary times; and at times of fire or explosion mines that depend on natural ventilation are virtually helpless and certainly are decidedly dangerous to those unfortunates forced to be in them.

Although ventilation and its control have almost always been deemed an integral part of coal mining, metal mines have rarely paid much, if any, attention to air circulation until forced to do so by occurrence of some untoward condition or accident. Yet metal mines actually have at least as great need of efficient circulation of air as have coal mines. The coal mine must remove the dangerous, explosive gas methane as well as fumes from explosives, and in some places other gases, such as CO_2 or hydrogen sulphide or nitrogen. Metal mines have much greater necessity to remove fumes from explosives because much larger unit quantities are used; frequently have occasion to remove CO_2, nitrogen, and other gases from strata; and even the coal miners' explosive gas, methane, is found occasionally. In addition, circulating air currents are urgently needed in many metal mines to reduce the excessively high humidity and temperature so frequently found in them but rarely in coal mines. The immense quantities of minutely fine particles of rock dust that float in the stagnant air of metal mines and that are very largely responsible for miners' consumption and other diseases so prevalent among metal miners in many regions could be removed very largely by adequate ventilation. The more or less generally accepted conclusion that coal miners have a relatively healthful occupation and that many metal miners contract diseases such as lead poisoning, miners' consumption, etc., and either die early in life or are incapacitated in middle age, is due almost

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wholly to the superior working conditions frequently found in coal mines, chiefly due to ventilation.

Our larger metal mines are comparable in many respects to an immense office building or a hotel. The various levels correspond to the floors of the building, except that in a mine they are 100 or more feet apart vertically and in a building they are 10 to 20 feet apart; the drifts and crosscuts correspond to the halls and corridors and the raises, stopes, and other working faces to the offices, sleeping rooms, etc. There is the difference, however, that in the mine there are no openings to correspond to windows to the outside, and only too frequently no openings between working places to correspond to interior doors between offices or rooms, which thus leaves only one opening to the working place. In general, the present practice, even in the better-ventilated metal mines, is to cause currents of air to flow along the main drifts and crosscuts (corresponding to halls and corridors of a building), with only such amounts of air going into the working places as might be expected to seep by diffusion into the rooms of a building if all outside doors and windows were tightly closed and the one door to the hall left open. The workers are usually engaged in some fairly strenuous occupation, such as drilling, timbering, shoveling, etc., which fills the air with fine dust (the most dangerous kind); or possibly they set off some dynamite to bring down rock or ore, thus liberating not only clouds of fine dust but also of smoke laden with poisonous gases; and only too frequently the surrounding walls are damp and have a temperature of 80° to 100° F., or even more, and the stagnant air of the place has a temperature of 80° to 100° or even higher, with a relative humidity of 90 to 100 percent.

Coal mines usually are required by law to have a ventilation system, but in many mines compliance with the provisions of the law is anything but complete, and it is due largely to this fact that accumulations of explosive gas ignite in scores of coal mines every year, sometimes with heavy loss of life.

Approximately in order of their importance, the main features that affect air in metal mines are (1) movement, (2) temperature, (3) relative humidity, (4) gases, and (5) dusts. In coal mines the order of importance would probably be (1) movement, (2) gases, (3) dusts, (4) relative humidity, and (5) temperature.

The matter of movement of air from the surface, through the working faces or places, and then back to the surface is by all means the most important consideration in effecting adequate ventilation of mines and in protecting the health and forwarding and maintaining the working efficiency of the underground workers. If adequate quantities of pure air are directed to the places where men work, most of the requirements of health and many of the demands of safety will be well served.

Temperature of underground air is affected by temperature of outside air in varying degree, depending on depth and extent of workings, air velocities, and other considerations; temperature of mine air is very definitely affected by underground rock and water temperatures, by quantity of air flowing, by oxidation (or decay) of timbers, coal, and ores, and by mine fires. It is also affected to a greater or less extent by friction due to velocity of flow, by moving of ground, firing of shots, and heat from lights and from breathing of animals. Heated air obtained from other mines and from electric motors and other machinery may seriously affect the local temperature of air of underground workings.

Relative humidity of underground air is affected to some extent by humidity of surface air, but much more vitally by moisture of walls of underground workings and especially by water dripping through the air. Quantity, temperature, and velocity of air flowing also ultimately affect the humidity of underground air. Water used in drilling, wetting ore or coal or mine surfaces, or in sprays, water blasts, etc., also contribute to mine-air humidity.

Gases to be found in mine air may come from surface air, from breathing of men and animals, from lights used, from firing of explosives, from compressed air used with machines or as blowers, from operation of various kinds of machinery, and from various coal, rock, or other strata encountered, as well as from mine fires, active or incipient.

Dusts found in metal-mine air are derived largely from dry drilling, blasting, shoveling or mucking, tramming or dumping rock or ore, timbering, hauling, etc. Probably well over 50 percent of all metal mines have siliceous material in ore or containing walls and hence have siliceous dust, which, as far as is known, is the most dangerous of all dusts, especially when it is taken into the lungs in large quantities in the extremely finely divided form thrown into the air by dry drilling, blasting, and mucking. Certain siliceous dusts seem to have far less injurious effects than others of essentially the same composition. Dusts of other than siliceous character, while thought not to be so definitely and immediately dangerous, are nevertheless likely to be harmful ultimately, especially if present in the air in very finely divided particles and in large quantities; the dusts of certain soluble lead ores affect workers through skin absorption as well as through breathing. Dust in coal mines occurs through processes somewhat similar to those in metal mining, in addition to those created by undercutting, overcutting, and shearing, and much dust is now being created by various kinds of mechanical loading devices. Coal dust may be very explosive under some conditions, and in addition it has a health hazard and its presence in large quantities in air very greatly reduces visibility; this, in turn, adds greatly to the danger of working in coal mines.

Some general conclusions are given below:

1. In mining, it appears that ventilation, fire protection and prevention, health, safety, and efficiency are very closely interrelated, and conditions, installations, and equipment in connection with any one of these considerations may vitally affect one or all of the others, detrimentally or otherwise.

2. There is at least as much reason for providing adequate ventilation for most metal mines as for providing ventilation for coal mines, though metal mines rarely provide ventilation until forced to do so by some untoward condition or occurrence; coal mines, on the other hand, usually ventilate more or less adequately from the beginning.

3. Every mine, coal or metal, should have a mechanically driven fan or fans (placed preferably on the surface) in a fireproof housing and capable of reversing air currents with a minimum of delay. Metal mines as well as coal mines should provide fan ventilation from start of opening to avoid dangers from explosive or other fumes, dusts, heat, etc., and to provide fresh air to workers. Mines that rely on natural ventilation are likely to have periods when air circulation is sluggish or ceases utterly or reverses in direction; and at time of fire so-called naturally ventilated mines are almost invariably at a decided disadvantage through inability to control the direction of air flow.

4. Ventilation should be under definite, constant supervision, preferably of one person, who should report to the highest officials. Each mine should be ventilated wholly within itself; interventilation of mines is likely to be dangerous, inefficient, and unsatisfactory. Any mine employing more than 200 persons should have one or more persons working exclusively on ventilation if health, safety, and efficiency are to be protected adequately.

5. Ventilation is probably the most effective dust-control practice, though it ranks second to wet methods under some conditions. Where ventilation can be applied effectively, dust can be removed from the air or its concentration can be kept so diluted as to render it almost harmless to workers; ventilation can minimize dust hazards of almost all kinds, including spontaneous combustion, though it may enhance hazards of dust explosibility in some instances. In some cases ventilation should be induced by exhaust methods, but in others forced or blowing systems are the more effective, particularly in underground work in places having high-temperature air due to rock or dripping water or other condition, such as rapid oxidation of surrounding rock, timber, etc. It is difficult to obtain really effective ventilation in such work as tunneling and metal mining, usually because ordinarily but one opening is driven instead of having workings in pairs, as in coal mines, where fresh air flows in one opening and return or contaminated air in the other. Conditions caused by dust may force the use of parallel openings in many tunneling and metal-mining operations of the future, and, notwithstanding the violent objection this suggestion will raise, there are good reasons for believing that in many cases there would be definite monetary savings if the parallel-opening system, with its numerous ventilation, health, drainage, and other advantages, were used instead of the present one-opening system, with numerous disadvantages and hazards and with about its only real advantage the fact that its use is and has been customary.

6. Dry drilling is unquestionably the dustiest work in mining, tunneling, quarrying, etc., and it continues to be used far too much in the United

States; certainly, if dry drilling is allowed at all, it should be done only with auger twist drills or with the simultaneous use of up-to-date dust traps. Wet drilling, as practiced in the United States with water forced or drawn through the drill steel by means of compressed air, is now under fire as producing relatively large quantities of dust, even though the material floating in the air usually is wet; some of this criticism is undeserved but some of it is legitimate. The trouble is due largely to the fact that the holes are collared or started dry and, in some cases at least, are drilled dry for several inches after starting, and the dust created by this dry starting impregnates the usually stagnant air of the ordinary underground-tunnel or metal-mine working place for much if not most of the working shift. In some cases the driller drastically limits the amount of water sent through the drill steel and, while nominally drilling wet, the actual practice closely approximates dry drilling with compressed air, which flows through the drill steel and forces out of the drill hole and into the air of the working place undue quantities of water-entrained dust particles. In some cases when the drill is out of repair, the driller allows far too much compressed air to flow through the drill steel. When present types of wet drills are used properly, the dust from drilling can be kept within reasonable limits, and this is actually being done by numerous alert and conscientious mining and tunneling companies at the present time. Some companies in the United States and Canada are experimenting with rock drills that do not allow compressed air to go through the drill steel but require the water to be forced through the steel by its own pressure; such drills are said to produce less dust than the usual types in which water is sent through the steel by compressed air; but the newer type of drill has been used relatively little in the United States or Canada. However, air dustiness can be kept well within safe limits if modern types of wet drills are operated with care and judgment and collaring is wet with plenty of clean, dirt-free water; if the drills are kept in good repair; if the proportions of water and compressed air flowing through the drill steel are regulated adequately; if the exhaust from the drill is prevented from impinging on nearby dusty surfaces of muck piles, floors, walls, or timbers, thereby throwing dust into the air; and if, insofar as feasible, the drilling of upper holes is reduced to a minimum, as upper holes, whether drilled dry or wet, are relatively heavy producers of dust in the air of working places.

7. While there are regulations in the United States to prevent dust formation in drilling, these regulations are not always observed, and this is the case especially in small mines or prospects. Miners, while recognizing the dangers from dust, often prefer to take the risk rather than endure the slight discomfort or extra trouble of using precautionary methods or devices; and mine and State officials seem to feel that unless the miner will willingly aid in protecting himself, they cannot force him to protect his own health and, incidentally, that of his family. Dust-prevention devices of proved success, such as modern self-rotating wet stopers, should entirely supplant dry drills and their use should be enforced upon both miners and operators in metal mines, large and small, irrespective of the silica content of the rock being drilled. There is absolutely no valid excuse for dry drilling in modern metal mining, and to date no workable device is available for removing dust in dry drilling in underground mines.

8. Next to dry drilling, blasting causes more finely divided dust to be thrown into working places through bringing down rock in mining, quarrying, and tunneling than anything else; and, in addition to throwing violently into the surrounding air immense quantities of finely divided dust, blasting, with the heavy charges of explosive required in many mining and tunneling operations, also impregnates the surrounding air as well as the muck piles with considerable quantities of poisonous gases, such as carbon monoxide, oxides of nitrogen, and, in some kinds of rock, hydrogen sulphide and other dangerous sulphurous fumes, practically all of which occur in such quantities and percentages under some circumstances as to asphyxiate persons who may breathe them or to cause serious illness, often more or less permanent. Many persons who have studied the incidence of dust disease are of the opinion that the breathing of even small quantities or percentages of extraneous or harmful gases such as carbon monoxide, oxides of nitrogen, hydrogen sulphide, etc., inflames or otherwise adversely affects the respiratory organs, especially the lungs, and makes them much more easily and readily susceptible to harm from the breathing of dust particles.

9. Past blasting practice most certainly must be modified and reformed if the employer is to avoid heavy penalties in compensation and other charges due to the inclusion of legislation on occupational diseases (one being dust disease) in the laws of the various States. If at all feasible, blasting should be done at the end of the working shift or on an off shift, and the dust- and gas-laden air should be removed or thoroughly diluted before the men return to work. Of course, ventilation is an essential agency in cleansing the air where blasting has been done, but, in addition to being ventilated, the place should be thoroughly wetted (walls, floor, roof or top, timbers, etc.) before blasting is done, and a water blast should be used during and after the blasting. The region should be wetted thoroughly upon return to the face region after blasting, and the muck pile should be kept well wetted at all times while it is loaded out, as the water not only lays the dust but also either absorbs or otherwise aids in diluting or eliminating harmful or poisonous gases that follow blasting and that usually cling to the blasted material. In general, the larger the quantity of explosive used, the more finely divided the blasted material, the more heavily the air will be impregnated with dust and smoke, and the greater will be the quantity of poisonous gases left at the place; hence, methods should be used that will tend to reduce the quantity of explosives used and of gases and dust produced. In this connection it will be found that the use of stemming or of some types of blasting plugs now available will more definitely confine the explosive, hence, increase its efficiency and reduce the quantity of explosive used and also reduce the amount of poisonous gas produced and possibly reduce the violence of the blast and its tendency to raise dust and disseminate it into the surrounding air. And it would be well for users of explosives to investigate types of explosives that are known to give off minimum quantities of harmful gases on detonation and to use them; also, the discontinuance of the use of fuse and the substitution of electric blasting would aid in reducing the amount of poisonous gases from blasting. Explosives that have been held in storage too long or that have been stored under unfavorable conditions as to moisture, temperature, etc., are likely to give off maximum quantities of harmful gases, if they

detonate at all; hence, utmost care should be taken in the storing of explosives to see that they are not held too long before being used.

10. While finely divided dust in mines is probably the chief cause of miners' consumption, it is now recognized that there may be other factors of almost equal influence, such as high temperatures and humidities, harmful gases, and lack of air movement, all of which can be remedied readily by ventilation. It appears that with a dry-bulb temperature below 75° F., mine working places may be comparatively comfortable irrespective of air movement or relative humidity. However, the presence of air heavily depleted of oxygen (say below 18 percent) or impregnated with gases such as CO_2, CO, oxides of nitrogen, etc., any or all of which may be produced in blasting, may produce uncomfortable or unsafe conditions; also, such places may be both uncomfortable and unhealthful if large quantities of finely divided dust are present.

11. With a dry-bulb air temperature above 75° F., comfort and maximum working efficiency can be attained only when the air is moving, this being especially true if the air has high relative humidity. The exact velocity necessary is a variable, depending largely upon the temperature and humidity. Saturated atmospheres, up to nearly blood temperature, may be made endurable and even to a considerable extent comfortable by providing sufficient velocity or movement.

12. In still air in metal mines with a temperature of about 85° F. and 90 to 100 percent relative humidity there is likely to be little or no harmful effect on persons completely at rest; but, with even moderate work, body temperature is likely to rise to over 100° F., blood pressure to fall perceptibly, and pulse beat to rise materially. In still air, with temperatures of 90° to 100° F. and with more than 90 percent relative humidity, even when the body is practically at rest body temperature rises quickly, reaching over 102°, blood pressure is likely to fall rapidly, pulse beat to increase abnormally and to be very sensitive to even slight exercise, perspiration to be very profuse, and dizziness, physical weakness, mental sluggishness, and headache are likely to be experienced; when even light work is attempted, these symptoms are likely to be augmented greatly.

13. Relative humidity, even up to the saturation point, does not appear to be harmful to health, comfort, or efficiency until the temperature runs above 75° F.; and if sufficient movement is supplied, high relative humidity is not particularly harmful until the temperature is well over 90° F.

14. With the exception of blind-end working faces, mine air in general is not particularly deficient in quality. However, the air at blind-end faces of drifts, crosscuts, raises, winzes, and stopes in metal mines is likely to be deficient in oxygen and high in nitrogen or CO_2 and possibly in CO, oxides of nitrogen, or other impurities. There are many cases on record of asphyxiation in metal mines from these gases. Similarly, dead-end unventilated places to the dip, to the rise, or on the level in coal mines may become depleted of oxygen through absorption by the coal or

timbers, or through intrusion of extraneous gases, nitrogen, carbon dioxide, methane, etc.

15. In stagnant air, comparatively small quantities of impurities, such as 0.30 percent or more of CO_2, 0.02 percent or more of CO, or oxygen slightly below 20 percent, cause headache, dullness, etc., and this is particularly true when the temperature is above 80° F. However, these small quantities of impurities are not likely to be noticeable when there is perceptible movement of the air.

16. Frequently blind-end working faces in mines, and more particularly in metal mines, have air so depleted of oxygen that a candle will not burn and carbide or other lamps must be used; hence, oxygen is below 18 percent and CO_2 may run several percent. Occasionally entire mines are found with this condition, which many mine managers regard as satisfactory. There is absolutely no question that men working in an atmosphere that will not support combustion of a candle cannot work with maximum efficiency and that their health will very likely suffer ultimately; certainly, safety is at all times endangered.

17. Mines with cool working places that allow men to work at top speed, especially when contracting, are likely to be extremely dangerous to health of workers unless provision is made to remove explosive fumes and other gases and fine dusts from working places with ventilating currents. Mines with high temperatures (above 75° F.) and high humidity (above 85 percent) are likely to lose from 25 percent to as much as 75 percent of the efficiency of workers; and workers are likely to become unhealthy ultimately unless moving currents of air are supplied to working places. Unhealthfulness and inefficiency are hastened and intensified if fine dust is present, especially siliceous dust, and if blasting is done, especially when men are in the mine.

18. Many accidents in mines are due to deficient ventilation. Failure to remove smoke and fumes from explosives prevents proper inspection of working places to make them safe, and, in addition, many men have been asphyxiated in explosives fumes. In hot, humid, stagnant air men are likely to be affected by dizziness or by lack of ability to think clearly or quickly, or they may faint and be killed; also, there are numerous instances where men have been known to have dropped dead in hot places, and scores of underground workers have been killed upon going into unventilated places in which the oxygen content of the air has been reduced in any of several ways when ventilation has not been maintained.

19. When the temperature of the air is above 75° F., mere movement of the air at working places is more important than anything else in giving adequate ventilation, provided the air is reasonably free of noxious gases and dusts.

20. Flowing air in underground passages rapidly takes the temperature of the surrounding rock. The rate of change is variable and frequently is as high as or higher than 1° F. for every 100 feet of travel. The

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temperature of still air underground rarely varies more than a few degrees from the temperature of the surrounding rock or water. Rock temperature generally increases with depth, the rate of increase varying from 1° F. or more per 100 feet of depth in certain districts of the western part of the United States to but 1/2° or 1/3° F. per 100 feet of depth in other regions, both of the United States and of foreign countries. Rock temperature may vary at the same depth in different kinds of material. A copper sulphide ore with quartz gangue in a mine in the western part of the United States had rock temperature several degrees higher than a zinc sulphide ore in quartz gangue in a parallel vein about 200 feet distant, both on the same level and both practically free of water.

21. Water standing still or flowing on the floor in mines readily communicates its temperature to surrounding air; water dripping through the air quickly brings the air practically to the temperature of the water drippers, and profuse water drippers will determine the temperature of the air almost irrespective of rock temperature. Water temperature underground is generally, but not always, the same as that of surrounding rock.

The dry-bulb temperature of air passing through fans frequently has increased several degrees Fahrenheit and the relative humidity has automatically decreased. Small electrically driven fans with galvanized-iron or canvas or other flexible tubing are being used widely in metal mines to carry air to dead ends. The galvanized iron has the advantage of allowing reversal of air currents to pull smoke out after blasting, then to force moving air to workers after the smoke has been removed; moreover, it does not decay as fast as canvas. In general, the flexible tubing must be used only in forcing air to the face, its advantages being low first cost, ready installation and removal, flexibility in conforming to bends or turns, and ease of repair. Moreover, because of its ready installation and removal, the flexible tubing can be brought close to the working face at ordinary times and can be removed easily prior to blasting to prevent its destruction. Either method readily admits of placing from 500 to 5,000 cubic feet of moving air per minute at the working face at comparatively small cost. The use of these small fan-tubing units in coal mines is hazardous in the extreme.

23. Compressed air from the end of air hose is used extensively to remove explosives fumes from faces or to ventilate hot, stagnant, blind-end workings in metal mines. These blowers deliver about 100 cubic feet of air per minute, but its temperature rarely varies much over 2° or 3° from the temperature of the rock and air of the working place. Such compressed-air blowers are inefficient as to removal of smoke or gases, provide comparatively little pure air, and cause very little reduction in the temperature of the surrounding air. Moreover, it costs about 100 times as much to place 1,000 cubic feet of compressed air at a working place as to circulate a like amount of air by ordinary ventilation methods. Compressed air is used only to a limited extent in ventilation in coal mines and its use is not only expensive and inefficient but also definitely dangerous.

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24. Cooling of air in mines is effected by use of ice or sprays of cool water, by refrigeration, by rapid coursing of air brought from the surface or carried slowly through workings with cool walls, and by excluding air from hot abandoned workings and return air from currents of active workings. Water sprays are not employed nearly as much as they should be; ice is used to a slight extent in the United States; refrigeration is costly and found only in a very few mines; and the rapid coursing of air currents from the surface, which can be brought about most efficiently by the establishment of definite separate splitting systems, is used only occasionally, though it is quick, relatively cheap, and efficient. Failure to seal abandoned places having decayed timber and hot rock or water sends much unnecessary heated and vitiated air into the mine, and re-using return air has the same effect.

25. At time of fire in a mine, lack of an efficient ventilation system may be disastrous. Each mine should have fans, which should be so placed as to be inaccessible to fire, have fireproof housing, be capable of quickly reversing air currents if desired, and, preferably, be installed on the surface. There should be a definite system of air splits such that fire in one place may not necessarily fill the entire mine with poisonous fumes. This provision is vitally important, yet very few metal mines have made even a reasonable attempt to establish this excellent safety feature. There should also be a system of doors near shafts in the levels leading from shafts such that the entire shaft may be isolated readily in case of fire, or any part of the mine may be isolated from the shaft. If the main haulage road or hoisting shaft or slope is used to transport workers into or out of the mine, it should not be on return air; otherwise, lives are very likely to be lost because of poisonous gases in case of fire or explosion. The ideal system as to mine openings through which men travel or must be hauled or hoisted is to have such openings essentially neutral as to air flow and supply them with only enough intake or fresh air to keep them free of gases, unduly cold air, etc.

26. Experimental work in mines reveals that after shafts that previously had ordinary exposed timbers are smooth-lined, friction generally will be reduced to such an extent that 50 percent or more additional air can be handled by the same power. Preferably, at least the intake air shaft should be fireproof and, if possible, all shafts or heavily inclined openings that carry air or through which men travel or are transported should be fireproofed, at least at and within several hundred feet of the intersection of such mine openings with the surface.

27. While the cost of establishing a ventilation system for a large mine is variable, the cost of operation is not particularly burdensome and it will usually be offset by savings in compressed air and in increased efficiency and health of employees, which frequently will equal the entire cost of the investment within a few years. If a fire or explosion occurs, an efficiently installed and operated mechanical ventilation system is of incalculable value, and the absence of such a safeguard is likely to result in heavy loss of property and possibly of life.

Appended to this report are some recently issued state regulations on gases from blasting, one in New York and one in California.

APPENDIX 1

NEW YORK STATE DEPARTMENT OF LABOR, NEW YORK CITY

RECOMMENDATIONS OF THE COMMITTEE ON CONTROL OF TOXIC FUMES IN BLASTING IN MINES, TUNNELS, AND SHAFTS TO THE INDUSTRIAL COMMISSIONER RELATIVE TO CONTROL OF TOXIC GASES AFTER BLASTING IN MINES, TUNNELS, AND SHAFTS

(a) Each case containing explosives for underground use shall be clearly marked in 1/4-inch or larger type with the designation "Fume Class 1", "Fume Class 2", or "Fume Class 3", to indicate the amount of poisonous gases produced. The amount of poisonous gases produced shall be the total volume of carbon monoxide plus hydrogen sulphide emitted in the Bichel gauge by a 1-1/4 by 8 inch cartridge of such explosive as determined by tests according to the standard procedure of the U. S. Bureau of Mines, in which tests the gases emitted shall not contain more oxygen than is sufficient to burn the combustible gases to their maximum oxidizable state. The amount of poisonous gases produced per 1-1/4 by 8 inch cartridge shall be less than 0.16 cubic foot for "Fume Class 1", from 0.16 to 0.33 cubic foot for "Fume Class 2", and from 0.33 to 0.67 cubic foot for "Fume Class 3." Explosives in cartridges smaller than 1-1/4 by 8 inches shall comply with the limits specified for the fume class of the 1-1/4 by 8 inch cartridge of that explosive.
(NOTE: The standard test procedure of the U. S. Bureau of Mines referred to in paragraphs (a) and (c) of these orders is recorded on pages 91 to 94 of U. S. Bureau of Mines Bulletin 346 entitled "Physical Testing of Explosives.")

(b) No explosive other than those in Fume Class 1 shall be used underground in any operation, except that if conditions in any operation warrant, the Commissioner may, at his discretion, grant permission for use of explosives in Fume Class 2 or Fume Class 3 when proper application has been made by an operator for such use.

(c) No explosive shall be used underground in any operation if the gases emitted in the Bichel gauge in tests, according to the standard procedure of the U. S. Bureau of Mines, contain more oxygen than is sufficient to burn the combustible gases to their maximum oxidizable state.

(d) No explosive which is packed in cartridges of less than one inch diameter shall be used underground in any operation.

(e) No explosive shall be used underground in any operation except in its original wrapper only, i. e., no explosive shall be used with its wrapper removed and no additional paper shall be wrapped around the explosive charge.

(f) No explosive which has obviously deteriorated due to improper storage, or to any other cause, shall be used underground in any operation.

(g) Permissible explosives used in underground operations having inflammable gas shall conform to all requirements of the United States Bureau of Mines as to permissibility and are therefore excluded from the requirements of paragraphs (a) and (b) of this order.

(h) No person shall enter a hazardous area created by a blast involving 25 pounds or more of explosives in any underground operation until at least 15 minutes have elapsed after such blast.

(i) No person shall enter with the intention of remaining, or shall remain, in a section containing gases produced by a blast in any underground operation unless the ventilation meets the requirements herein prescribed. The ventilation must be maintained so that in the breathing zone of the section the concentration of carbon monoxide, as determined by a carbon monoxide detector approved by the Department of Labor, does not exceed 0.030 percent by volume at the time of entrance into such section and does not exceed 0.015 percent at the end of one hour after entrance and 0.010 percent at the end of two or more hours thereafter; provided, however, that this regulation is not intended to prevent entering into, passing through, or remaining in localized sections for a period not exceeding 5 minutes in concentrations of carbon monoxide of 0.060 percent to 0.100 percent or for a period not exceeding 15 minutes in concentrations of carbon monoxide of 0.030 percent to 0.060 percent.

When the concentration of carbon monoxide and the conditions of exposure to this gas in a section exceed the limitations stated in the foregoing paragraph, adequate respiratory protection shall be provided for and shall be used by any person entering said section.

A contractor or operator shall designate a capable man whose duties it shall be (1) to make such tests and examinations as are necessary to establish conditions with respect to ventilation and poisonous gas concentrations in sections containing such gases from blast from explosives; (2) to direct and control the entrance into and periods of exposure of all persons within such sections; and (3) to keep a dated record of all such tests and examinations, which record shall be available for examination by inspectors of the Department of Labor at all times.

(j) In addition to the foregoing, in any shaft or tunnel of a construction project the minimum amount of fresh air introduced into the shaft or tunnel heading shall be the larger of the two following alternatives: (1) 100 cubic feet per minute per man occupying the section within 200 feet of the blasted face, and (2) 5 cubic feet per minute per cartridge of explosive used in blasting that face.

In all blasts involving delay electric blasting caps in shafts or tunnels, each shot hole must be adequately stemmed with noncombustible material or the explosives confined in some other manner approved by the Industrial Commissioner.

No internal-combustion engine shall be used in any shaft or tunnel of a construction project except as same has been approved by the Department of Labor.

A contractor doing work involving shafts or tunnels, the total contract value of which work is $250,000 or more, shall employ a licensed professional engineer whose duty shall be (1) to make such tests and examinations as are necessary to establish conditions with respect to ventilation and poisonous gas concentrations in sections containing such gases from blasts from explosives; (2) to direct and control the entrance into and periods of exposure of all persons within such sections; and (3) to keep a dated record of all such tests and examinations on a form provided for the purpose by the Department of Labor, to certify same, and mail same monthly to the Department of Labor.

APPENDIX 2. EXPLOSIVES

ORDER 1745. EXPLOSIVES FOR UNDERGROUND USE.
FROM MINE SAFETY ORDERS
CALIFORNIA - INDUSTRIAL ACCIDENT COMMISSION - 1938

(Note - Order 1745 shall not apply to explosives used in coal mines.)

(a) Each case containing explosives for underground use shall be clearly marked with the class that indicates the amount of poisonous gas produced per 1-1/4 by 8-inch cartridge.

(b) For the purposes of this order, the poisonous gas-producing properties of an explosive shall be the volume of carbon monoxide plus hydrogen sulphide emitted by 1-1/4 by 8-inch cartridges as shown by tests in the Bichel gage according to the standard procedure of the U. S. Bureau of Mines, provided the resulting gases do not contain more oxygen than is sufficient to burn the combustible gases to their maximum oxidizable state.

(c) No explosive shall be used underground if the gases emitted in tests in the Bichel gage according to the standard procedure of the U. S. Bureau of Mines show more oxygen than is sufficient to burn the combustible gases to their maximum oxidizable state.

(d) Cases containing explosives for use underground will be considered clearly marked if they bear in 1/4-inch or larger type the designation "Fume Class 1", or "Fume Class 2", or"Fume Class 3", provided the explosives contained in the cases so marked comply with the following classification:

Cubic feet of carbon monoxide plus hydrogen sulphide per 1-1/4 by 8-inch cartridge when tested according to paragraph (b)

Fume Class 1 -- Less than 0.16
Fume Class 2 -- 0.16 to 0.33
Fume Class 3 -- 0.33 to 0.67

Explosives in cartridge sizes smaller than 1-1/4 by 8 inches shall not emit more poisonous gases per cartridge than are emitted by 1-1/4 by 8-inch cartridges as defined above.

(e) No explosive shall be used underground in the presence of combustible gases and/or combustible dusts unless specific application is made by the operator to, and the use approved by, the Commission.

(f) Explosives complying with the requirements of Fume Class 1 may be used in underground workings free from combustible gases and/or combustible dusts without specific application by the operator to

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the Commission provided the explosive (1) has not deteriorated in prolonged or improper storage, (2) is properly charged and stemmed with noncombustible stemming, (3) does not have a burden so heavy that it will obviously be liable to blow out, (4) is not overloaded, and (5) the mine is properly ventilated as required by Mine Safety Order 1778. Before blasting, the men must be removed a safe distance from the face and shall not return to the face until the poisonous gases have been cleared.

(g) Explosives complying with the requirements of Fume Class 2 and Fume Class 3 shall not be used underground unless the operator has made specific application to and has shown to the satisfaction of the Commission that adequate ventilation has been provided and that the operating requirements specified in paragraph (f), (1), (2), (3) and (4), will be met.

(h) All explosives packed in cartridges must be loaded in the original cartridge without alteration of the quantity of the wrapper.